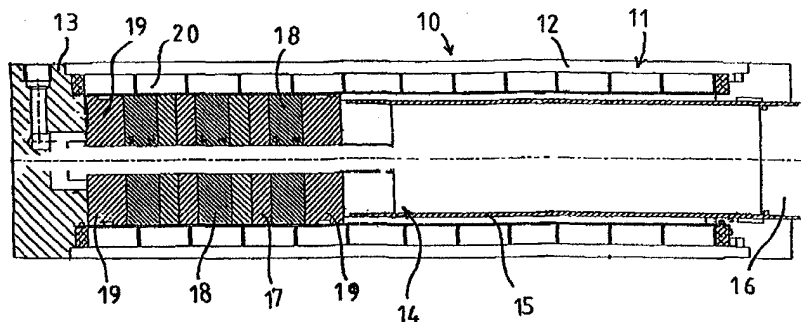


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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/GB98/00594 <b>(22) International Filing Date:</b> 24 February 1998 (24.02.98)  <b>(30) Priority Data:</b> 9703821.0 24 February 1997 (24.02.97) GB  <b>(71) Applicant (for all designated States except US):</b> SHOSTAR LIMITED [GB/GB]; 1 New Square, Lincoln's Inn, London WC2A 3SA (GB).  <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> DENNE, Phillip, Raymond, Michael [GB/GB]; 7 Lyndon Gate, Chine Crescent Road, Bournemouth BH2 5LW (GB).  <b>(74) Agent:</b> CRAWFORD, Andrew, Birkby; A.A. Thornton & Co., Northumberland House, 303-306 High Holborn, London WC1V 7LE (GB).		<b>(81) Designated States:</b> GB, JP, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

**(54) Title:** ELECTROMAGNETIC APPARATUS FOR PRODUCING LINEAR MOTION**(57) Abstract**

An electromagnetic ram comprises two tubes (12, 15), one nesting within the other and closed at opposite ends to form an enclosed space. An electromagnetic system, either having coil or moving coil or moving armature is provided to cause relative linear motion between the two tubes (12, 15). One of the tubes has an opening to permit fluid flow into and out of the enclosed space. The construction provides a ram which is capable of resisting lateral loads.

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### Electromagnetic Apparatus for Producing Linear Motion

The present invention relates to electromagnetic apparatus for producing linear motion.

5           The conventional way of producing linear motion is by using a hydraulic or pneumatic piston and cylinder device or by using a rotational device such as an electric motor with a rotary to linear transformation mechanism. Each solution has its strengths and weaknesses. In recent years a further solution, the dc or ac linear motion, has been used particularly where precise positioning of a  
10           movable load is required as a linear motion avoids the need for a rotary to linear transformation mechanism. A disadvantage of the linear motor is that it produces an actuator which is asymmetrical with a strong force imbalance between the armature and the stator in that they are mutually attracted. Further, linear motors have been designed to be placed in a horizontal position, driving the load along  
15           tracks or bearings within or alongside of the motor.

          In WO 93/01646 there is disclosed an electromagnetic device arranged to operate as a piston and cylinder device. Conceptually, the stator of this device can be considered as being the stator of a conventional motor slit along a plane passing through the axis of the armature and unrolled. The uncut ends of the stator  
20           are now brought together to produce a tubular stator forming a cylinder. The piston member is provided with ring shaped magnetic portions.

          Further, such a device can be used in the construction of a combined electromagnetic/pneumatic actuator. The pneumatic part of the actuator provides a static force which may be sustained indefinitely with little or no power  
25           consumption whilst the electromagnetic part, working simultaneously, is capable of providing extremely fast changes in net actuator force and therefore provide the control and precision which are missing from a pneumatic actuator.

          The present invention is a modification to the device disclosed in WO

93/01646 and is intended to provide an electromagnetic apparatus for producing linear motion which must be capable of causing linear motion at angles between the horizontal and the vertical and be totally enclosed without any significant stray magnetic fields.

5           The present invention provides a device for producing a linear motion comprising two cup-shaped members, one sliding within the other and forming an enclosed space, a first means for producing a magnetic field alternating in polarity along at least a part of the length of one of the cup shaped members, and a second means for producing a further magnetic field alternating in plurality along  
10       portion of the length of the other of the cup shaped members for cooperation with the first magnetic field, and means for controlling the polarity of at least one of the magnetic fields whereby to cause linear relative movement between the two cup-shaped members.

          Preferably, one of the cup shaped members has an opening to permit  
15       fluid flow into and out of the enclosed space.

          The device may be constructed as a moving coil or moving magnetic arrangement as desired. Preferably the coils are energised by a three phase alternating supply.

          Depending on the application, the fluid may be air or a different  
20       compressible fluid. It should be noted that the fluid within the device does not itself need to be compressible providing that it is connected directly to a reservoir filled with air or other compressible gas whose pressure is modified by the movement of the non-compressible liquid, so that the liquid itself appears to be compressible.

25           In order that the present invention be more readily understood, embodiments thereof will now be described by way of example with reference to the accompanying drawing which shows diagrammatically the basic concept of an electromagnetic actuator according to the present invention.

An electromagnetic device for producing linear motion comprises two relatively movable cup-shaped members which are arranged to slide one within the other with their closed ends forming the ends of the device. One of the members is arranged to constitute a so-called stator member while the other can be considered as forming either a moving coil or a moving magnet armature. It is apparent that a number of different devices can be constructed within this broad description and the present description will refer to only one such construction.

Turning now to the drawing, the electromagnetic device is indicated by the reference numeral 10 and comprises a first cup-shaped member 11 which, in this case, is fabricated from a tube 12 one end of which is closed by an end member 13 which is provided with a passageway 13a arranged to permit a reservoir (not shown) to be connected to the member 11. The passageway 13a opens into the interior of the cup shaped member.

Mounted within the tube 12 is a further cup-shaped member 14 fabricated from a tube 15 one end of which is closed by an end member 16. The cup shaped members 11 and 14 are disposed so that their end closure members 13 and 16 are disposed opposite one another. Consequently, by causing relative movement between the two cup shaped members 11 and 14 one can alter the volume within the device.

Any suitable electromagnetic system for causing relative movement between the members 11 and 14 can be used. In the present example, the open end of the tube 15 is provided with a magnet section 17 which extends only part way along the overall length of the cup-shaped member 14. It will be seen that the magnet section 17 is annular but the bore of the annulus is of smaller cross-sectional area than the bore of the tube 15. In this embodiment the magnet section is formed by a series of permanent magnets linearly arranged and disposed around the circumference of the cup-shaped member 14. The magnets 18 are contained between pole pieces 19.

The magnet section 17 thus produces a magnetic field which is arranged to cooperate with a further magnetic field formed when coils (not shown) located in formers 20 are energised from a suitable source (not shown) in order to produce linear motion. In the present invention, it is intended that the coils will be energised from a three-phase alternating current source and this means that, as shown, there are four sections of coils each with three coil elements making a total of twelve coil elements in total.

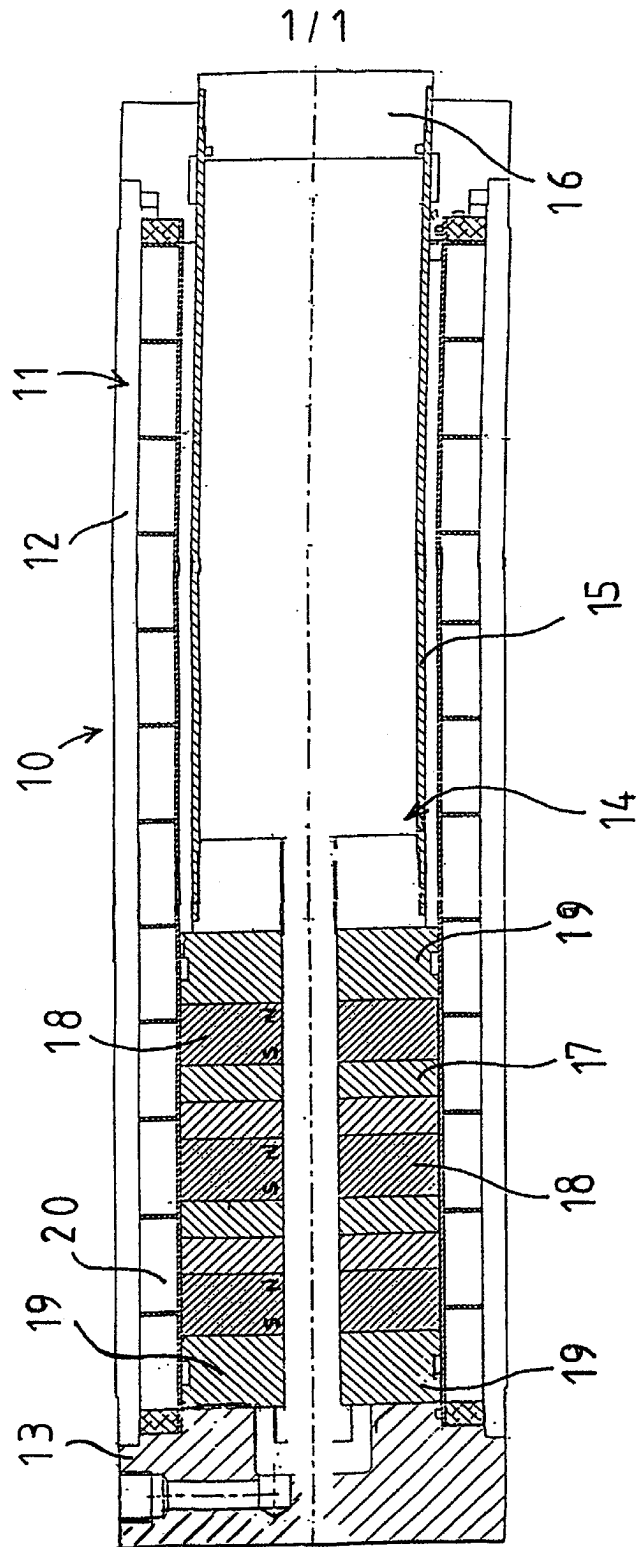
With this arrangement, assuming that the relative axial positions of the two cup-shaped members is determined using a suitable position sensor and a sine/cosine resolver, the resulting device can produce an accurate stroke.

It will be appreciated that due to the fact that the arrangement utilises two cylinders one sliding within the other, and the cylinders are carefully journaled to each other using suitable bearings, this arrangement is very resistant to lateral loads. Additionally, the above arrangement can be effectively sealed so that the device can be used in hazardous or difficult environments.

Various modifications can be made such as the electromagnetic arrangements can be readily altered in any convenient fashion. Also, if necessary vent holes can be formed in the tube 15 to prevent any vacuum effects between the relatively movable tubes which might result in resistance to movement of the tubes.

## CLAIMS

1. A device for producing a linear motion comprising two cup-shaped members, one sliding within the other and forming an enclosed space, first means  
5 for producing a magnetic field alternating in polarity along at least a part of the length of one of the cup shaped members and a second means for producing a further magnetic field alternating in polarity along a portion of the length of the other of the cup shaped members for cooperation with the first magnetic field, and means for controlling the polarity of at least one of the magnetic fields whereby  
10 to cause linear relative movement between the two cup shaped members.
2. A device according to claim 1, wherein the coils are energised by a three phase alternating supply.
- 15 3. A device according to claim 1, wherein one of the cup shaped members has an opening to permit fluid flow into and out of the enclosed space.
4. A device according to claim 3, wherein the fluid is compressible.
- 20 5. A device according to claim 4, wherein the fluid is a gas.
6. A device according to any one of the preceding claims, wherein the cup-shaped members are formed by tubes closed at one end and nesting one within the other.
- 25 7. A device according to any one of the preceding claims and comprising a reservoir connected to the interior of the enclosed space formed by the two cup-shaped members.





# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 98/00594

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 H02K41/02 H02K7/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 017 420 A (DRUM ENG CO LTD) 3 October 1979	1-3
Y		4,5,7
A	see page 1, line 21 - line 54; figures 1,2	6
Y	WO 93 01646 A (DENNE DEV LTD) 21 January 1993	4,5,7
A	see page 1, line 20 - line 24 see page 3, line 4 - line 14; figure 22	1-3,7
A	US 5 166 563 A (BASSINE STUART) 24 November 1992 see column 3, line 23 - line 62 see column 6, line 32 - column 7, line 6; figures 1-4	1-7
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☒ Further documents are listed in the continuation of box C.

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Name and mailing address of the ISA  
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NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 560 894 A (STOLL KURT) 24 December 1985 see figure 1	1,6
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